

Estimation of Doppler gradients at rest and during exercise in patients with recoarctation of the aorta

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Abstract

In patients with suspected recoarctation of the aorta the estimation of the pressure difference between the arms and legs is an important part of the examination. Because this difference is often augmented when the circulation is stressed by exercise, exercise tests are a useful part of the evaluation. Doppler echocardiography was used to estimate this pressure difference in 16 adult patients in whom simultaneous pressure and Doppler recordings were made both at rest and during exercise. There was a close correlation between the invasive peak instantaneous gradient and the Doppler gradient both at rest and during exercise. There was only a moderate correlation between the invasive peak to peak gradient and the Doppler gradient at rest and during exercise.

Doppler echocardiography is recommended as an easy and accurate method of estimating the peak instantaneous gradient both at rest and during exercise in patients with suspected recoarctation.

In patients operated upon for coarctation of the aorta a good repair results in normal blood pressure and no significant aortic obstruction shown by angiography or magnetic resonance imaging.^{1,2} Frequently, however, patients have near normal blood pressure at rest that becomes abnormal during exercise. Whether or not this is always the result of a recoarctation is debatable.^{3,4} The increased flow during exercise is expected to unmask an obstruction that may not be evident at rest, and an exercise test is often included in the follow up examination of these patients.⁵⁻⁷ When patients are studied during exercise, blood pressure is usually recorded immediately after exercise by two blood pressure cuffs at the wrists and ankles and the pressure difference is derived from these measurements.

Though several studies have reported acceptable correlation between gradients measured invasively and by Doppler echocardiography in these patients,⁸⁻¹⁰ most have dealt with a mixture of native coarctations and recoarctations^{9,11,12} and few have examined pressure differences measured simultaneously by catheterisation and Doppler echocardiography. The inclusion of preobstruction velocities in the calculation of the Doppler gradient by the modified Bernoulli equation is controversial^{8,11,12} as is the existence of a sig-

nificant difference between peak instantaneous gradients and peak to peak gradients in these patients.⁸

Our study examined the use of Doppler echocardiography to estimate gradients at rest and during exercise in an homogeneous group of patients with suspected recoarctation and we performed the invasive and non-invasive measurements simultaneously.

Patients and methods

PATIENTS

We examined a consecutive series of 16 adult patients (three women and 13 men) with a mean age of 30 years (20-55 years). All of them had had resection and end-to-end anastomosis of their lesions.

METHODS

Invasive studies

Pressures were recorded with fluid filled catheters connected to mechanico-electrical transducers interfaced with an ultraviolet strip chart recorder and calibrated against a hydrostatic standard. In eight patients a pull back procedure was performed and the proximal and distal pressure recordings were superimposed with close matching of RR intervals of similar duration. In eight patients a dual catheter technique was used whereby the two catheters were positioned immediately proximal and distal to the recoarctation. The pressures, peak instantaneous gradients, and peak to peak gradients of 3-5 beats were averaged.

Non-invasive studies

The aortic arch was examined with pulsed and continuous wave Doppler on a Vingmed's CFM 700 or 750. The velocities in the ascending aorta were recorded with pulsed Doppler echocardiography and the coarctation jet was recorded with a 2 MHz non-imaging transducer positioned in the suprasternal notch.

The Doppler gradient were calculated according to the simplified Bernoulli equation¹³: $p = 4(V_2^2 - V_1^2)$, where p = gradient (mm Hg), V_1 = ascending aortic velocity (m/s), and V_2 = coarctation jet velocity (m/s). The average values of 3-5 beats were estimated.

All patients were examined at rest and during supine exercise in the catheterisation laboratory. When a satisfactory position of the Doppler probe was achieved Doppler velocities and invasively measured pressures and gradients were recorded simultaneously.

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Non-invasively measured (Doppler) gradients (mm Hg) and invasively measured peak instantaneous and peak to peak gradients at rest and during exercise

Case	Rest			Exercise		
	Doppler gradient	Invasive peak inst gradient	Invasive peak to peak gradient	Doppler gradient	Invasive peak inst gradient	Invasive peak to peak gradient
1	25	27	16	62	73	64
2	49	40	6	92	92	60
3	19	20	20	44	72	72
4	12	16	0	34	52	48
5	27	44	20	37	48	26
6	12	16	0	27	32	28
7	41	48	42	85	76	68
8	28	34	16	51	66	58
9	12	9	8	20	21	20
10	20	22	8	56	76	14
11	20	32	23	41	64	52
12	9	20	4	22	24	20
13	7	8	2	31	44	36
14	53	46	36	92	88	76
15	18	39	22	37	52	38
16	21	28	12	44	42	20

Interobserver variability

The last 10 patients were examined by two experienced examiners. The differences between the two observers were calculated.

STATISTICAL ANALYSIS

Correlation and linear regression analysis were used to compare non-invasively and invasively measured pressure drops. Agreement between the methods was assessed by the method of Bland and Altman.¹⁴

Results

The table shows the invasively and non-invasively measured results. The correlation between invasive peak instantaneous gradients and Doppler gradients at rest and during exercise was 0.92 (SD = 9 mm Hg) ($n = 2 \times 16$). There was a good agreement between the Doppler estimated gradient and the invasively measured peak instantaneous gradient (fig 1) and between the Doppler gradient and the invasively measured peak to peak gradient (fig 2). Figure 3 shows the pressure recordings of patient 14 at rest and emphasises the difference between peak instantaneous and peak to peak gradients in these patients.

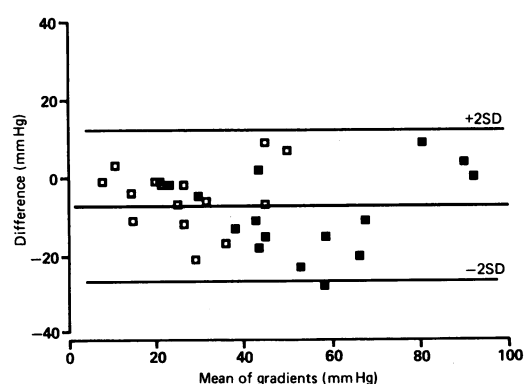


Figure 1 Difference between the Doppler gradient and the invasively measured peak instantaneous gradient plotted against the mean of both methods. Open symbols are results recorded at rest and solid symbols the results during exercise. One open symbol represents the results of two patients.

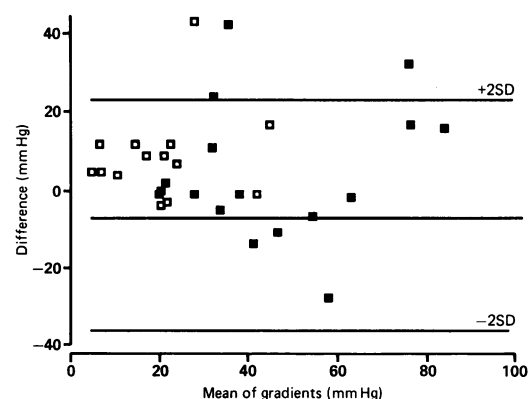


Figure 2 Difference between the Doppler gradient and the invasively measured peak to peak gradient plotted against the mean of both methods. Open symbols are results recorded at rest and solid symbols the results during exercise. One open symbol represents the results of two patients.

The mean difference in calculated gradient between the two observers was 1.3 mm Hg (0–3 mm Hg) at rest and 3.3 mm Hg (1–5 mm Hg) during exercise.

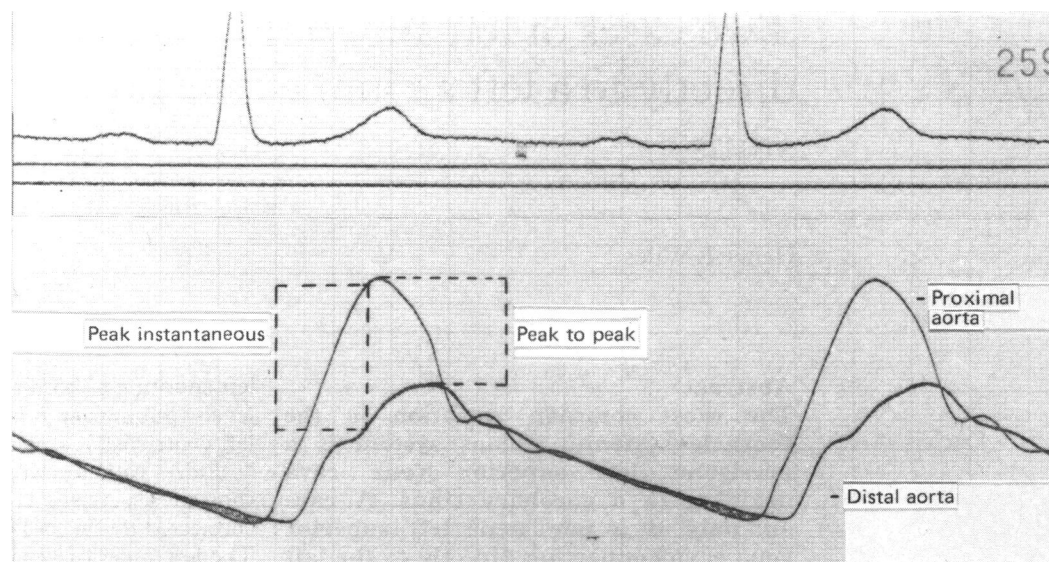
Discussion

We showed that it is possible to estimate the gradient across the coarctation site by Doppler cardiography even during exercise. The method is easy to perform and certainly far more simple than the use of two blood pressure cuffs. It has also the advantage over the cuff method that the gradient is estimated during exercise and not subsequently within a variable time interval. We believe that this is an important point; it will be addressed in a later study. Our results also showed the closest correlations between the Doppler gradients and the invasive peak instantaneous gradients. This finding is expected from findings in patients with aortic stenosis.¹⁵

There are frequently considerable differences between the Doppler gradient and the invasively measured peak to peak gradient (table). At least three factors will tend to give a Doppler gradient larger than the invasive peak to peak gradient: (a) the difference between peak instantaneous and peak to peak gradient as shown in fig 3; (b) if the velocities proximal to the obstruction are not subtracted this will magnify the Doppler gradient; and (c) the effect of pressure recovery distal to the obstruction¹⁶ will influence the results. A small angle error almost always affects Doppler echocardiography and when this is significant the Doppler technique will underestimate the peak instantaneous gradient. We believe this explains why the Doppler gradient was less than the peak to peak gradient in some of our patients. Our Doppler results showed larger gradients than the invasive peak to peak gradient in most patients.

Simultaneous invasive and non-invasive measurements are important for the comparison of gradients in these patients with varying numbers and sizes of collateral vessels where the relation between flow, gradients, and degree of obstruction is more complicated than when

Figure 3 Typical recording of proximal and distal pressures showing the difference between peak instantaneous and peak to peak gradient.



there is a valve lesion. It was not the purpose of this study to determine the clinical implications of the measured pressure drops and their relation to anatomical obstruction. We found that even during exercise reliable Doppler-derived gradients can be recorded with low inter-observer variability.

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